Saskatchewan Technology Enhancement Program

Forest Fuel Classification Using Landsat MSS Digital Data

by

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Saskatchewan Parks, Recreation and Culture
Prince Albert, Saskatchewan

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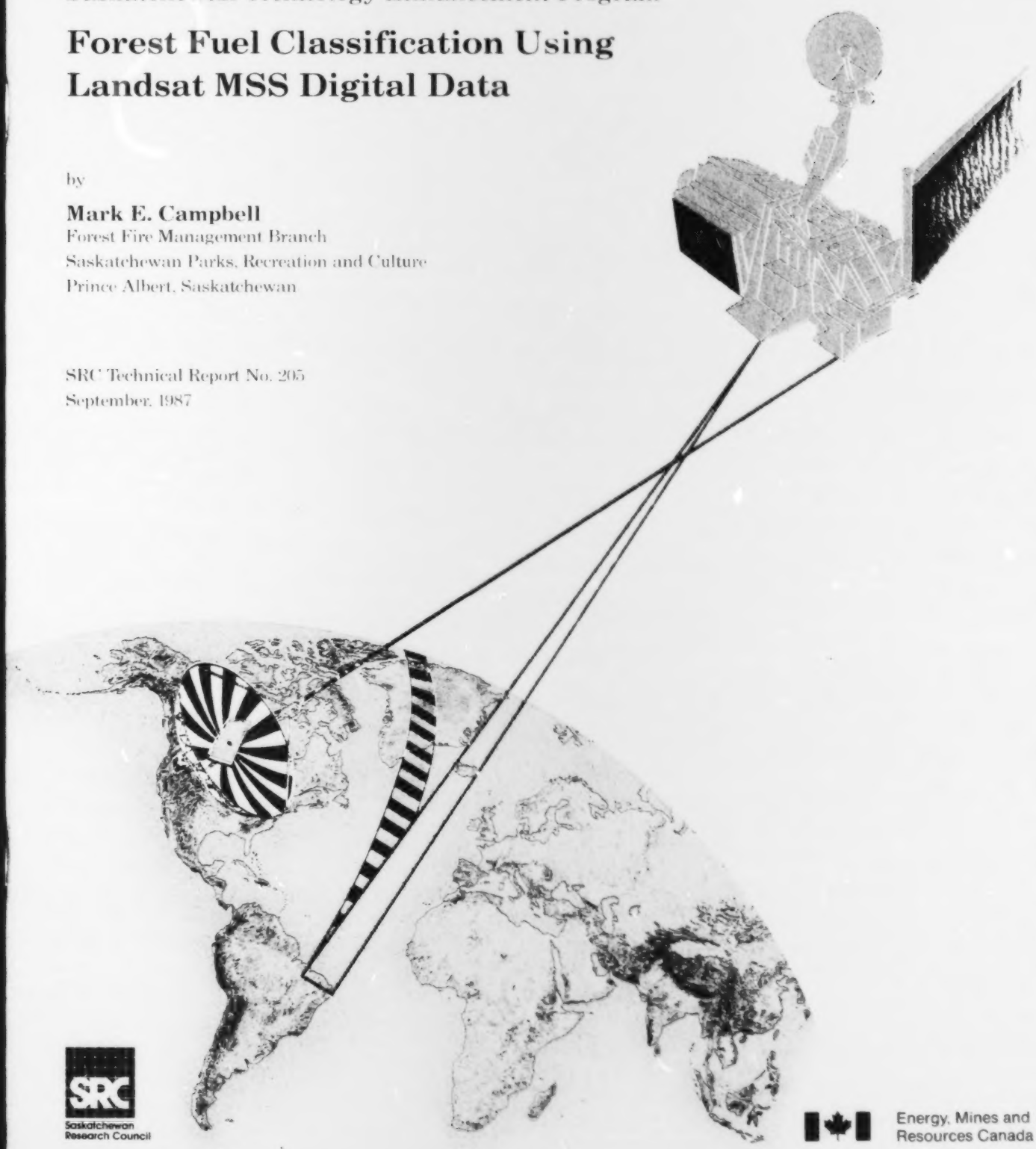

SRC
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ABSTRACT

Saskatchewan Parks, Recreation and Culture (SPRC), Forest Fire Management Branch (FFMB), engaged in a pilot project under the Saskatchewan Technology Enhancement Program (STEP), in an attempt to discover a cost effective and timely method of classifying forest fuel types in the forested areas of the province.

This process involved the classification of various fuel types through the use of Landsat MSS data, as processed by the DIPIX system located in the Saskatchewan Research Council (SRC) complex, Innovation Boulevard, Saskatoon.

A forest fuel classification map was produced for the Wapawekka map sheet (73-I) at a 1:250,000 scale.

The project has demonstrated that Landsat MSS data is useful in creating forest fuel classification maps, and hopefully this mapping program will be carried on in the future.

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1. BACKGROUND

Following an operators training course held at SRC, a project was initiated under STEP to evaluate the effectiveness of utilizing MSS data for the purpose of forest fuel mapping.

The Wapawekka sheet was selected for classification because of the diverse nature of the forest cover types within the study area. In addition, a large number of chronologically distinct burn areas were available for examination, as well as cutovers in various stages of regeneration.

It was hoped that the use of remote sensing techniques could provide basic pre-suppression fuel type maps that would resemble as closely as possible the fuel types identified in the Canadian Forest Fire Danger Rating System (CFFDRS). This would assist in fire spread predictions, priorization of initial attack efforts, and general decision support functions.

This information will also be useful in applications involving the Canadian Forest fire danger Rating system (CFFDRS), which involves two basic components.

The first input involves the Canadian Forest Fire Weather Index (FWI), which is derived from a series of calculations based on weather conditions. These calculations provide a numerical rating of the relative fire potential that exists in a specific area of observation.

The other major informational requirement of the CFFDRS involves the identification of specific fuel types, as fire behavior will vary significantly given different fuel types.The production of high quality forest fuel maps through digital analysis can, therefore, provide great assistance to fire managers in the future.

2. STUDY AREA

2.1 Location

The area covered by the Wapawekka map sheet lies in east central Saskatchewan between 54° and 55° north latitude, and 104° and 106° west longitude (Figure 1).

It occupies approximately 1.5 million ha (14,244 km^2) (Head et al. 1981).

2.2 Physiography

The study area is located predominately within the mixedwood section of the southern boreal forest. Typical hardwood species encountered would include trembling aspen (*populus tremuloides*), balsam poplar (*populus balsamifera*), and white birch (*betula paperifera*). Common softwoods would include black spruce (*picea mariana*), white spruce (*picea glauca*), tamarack (*larix laricina*), as well as balsam fir (*alres balsamea*).

Less dominant species of shrubs and brush would typically include willows (*salix* sp.), rose (*rosa* sp.) and dogwoods (*corylus* sp.).

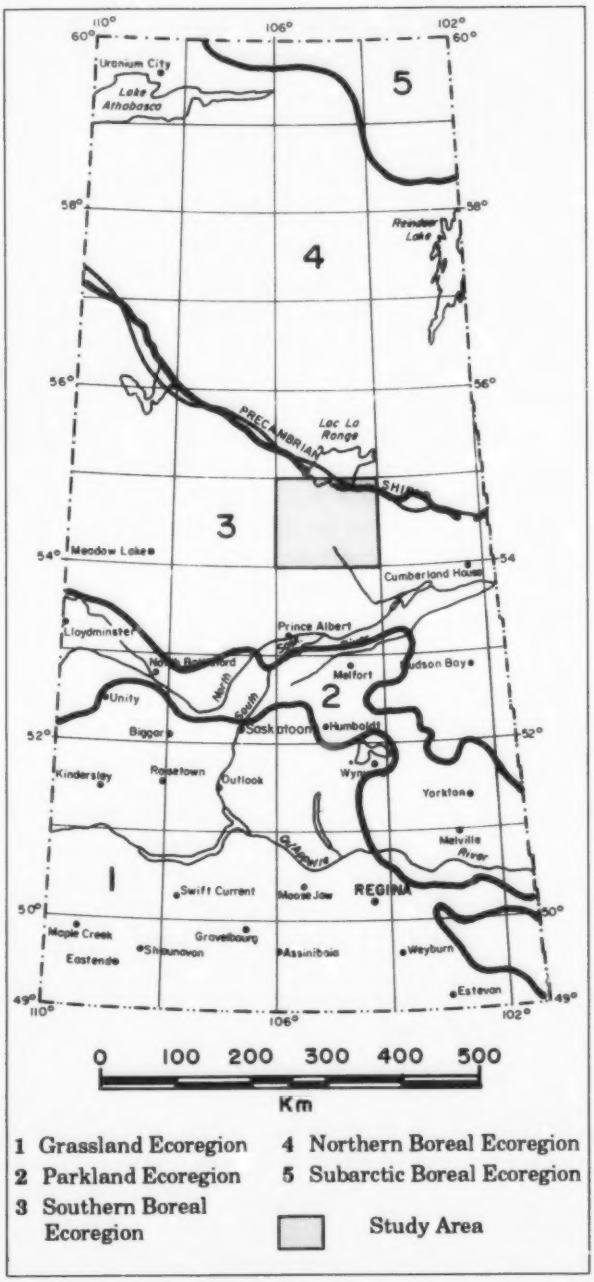

Figure 1. Location of Study Area.

3. METHODS

3.1 Data Acquisition

Microfiche imagery files were viewed at the Prince Albert Satellite Station to ensure the selection of appropriate, cloud-free imagery of the study area.

A computer compatible tape of June 10, 1984 imagery was selected for analysis.

This tape was purchased in geometrically uncorrected format, with all of the standard corrections.

In addition to digital information, air photos were obtained from SPRC Forestry Branch for select subareas, at a scale of 1:12,000 (approximate).Forest inventory maps (FIM's) were also available for the entire study area, with 1:25,000 scale being utilized for classification verification.

Training areas for supervised classification were selected in locations familiar to the operator. Due to the familiarity with various areas acquired during a period of two years work experience in the study area, relatively pure stands could be selected for training purposes, with a high level of confidence.

Forest fire histories and composite chronological maps of major burns were also used in delineating suitable training areas.

3.2 Classification Methods

3.2.1 Image Enhancement

During preliminary work with the image analysis system, extensive work was performed to determine the suitability of various enhancement options. Linear enhancements were applied to all subareas to accentuate the differences in the various vegetation cover types.

The cover types chosen for an initial classification of this area are illustrated in Table 1.

Table 1.
Digital Classes used for Initial Classification of the Wapawekka Map Sheet.

Cover Types	CFFDRS Fuel
1. LAKES	---
2. SOFTWOODS	C-1, C-2, C-3
3. HARDWOODS	D-1
4. HARDWOOD DOMINANT MIXEDWOOD	M-2
5. TREED BOG	C-2
6. OPEN BOG/MARSH	01
7. WILLOW/SHRUB	M-2
8. OPEN JACK PINE	C-7
9. BURNS (1977-83)	---
10. BURNS (1984)	---
11. REGENERATING CUTOVER	C-4
12. RECENT CUTOVERS	S-1

3.2.2 Preliminary Classification

Initially, the parallel piped classification option was applied to a number of relatively diverse subareas. This provided a preliminary indication of the vegetation cover separation that could be achieved through use of the system.

Classification was performed utilizing both the training area and individual pixel classification methods available within this task.

3.2.3 Unsupervised Classification

Six subareas were selected from within the study area, to adequately deal with any reflectance variations that may have occurred within any given area.

Histograms in Bands, 7, 6, 5 and 4 were created for each subarea, and searched for local maxima peaks. Maxima were stored and later merged into theme files based on visual interpretation of cover types represented. Those maxima which did not appear to fall within any

one specific class were deleted from further analysis.

Following the completion of the unsupervised classification, comparisons were made between cover types as determined through digital methods, and ground cover data including air photos, FIM's, and homogeneous stands identified through "local knowledge" of the study area.

Accuracy levels for signatures were determined by comparing the composition of known forest stands within the study area to the results obtained through the unsupervised classification.

If this comparison indicated an acceptable level of accuracy (approximately 80%), the signature files in question were retained for use in classification of the entire image.

3.2.4 Supervised Classification

Supervised classification was initially performed on the same subareas selected during the unsupervised classification described earlier. Additional subareas were later added to deal with classification problems involving edge pixels of water bodies and specific types requiring further classification.

Training areas were delineated through the use of air photos, FIM's and personal familiarity with the forest cover types of the area.

Classification results were also verified through the above sources of ground data. Suitable signatures were retained for use in classification of the entire image.

3.2.5 Combining Signature Files

Signature files for representative cover types obtained through both the supervised and unsupervised classification were combined through a maximum likelihood classifier, and the signature files generated through this amalgamation were used to produce the final classification of the image.

3.2.6 Accuracy

Definitive locations were difficult to pinpoint when comparing the FIM vs. digital classification, which made the comparison of individual pixels virtually impossible. Trends and cover patterns, however, were compared and accuracy levels checked in this manner.

SRC staff performed a detailed pixel-by-pixel comparison between the digital classification (1:25,000 reproduction), and a 1:25,000 scale FIM. As mentioned, this proved extremely difficult, so accuracy data could not be quantified with a reasonable level of confidence.

Further assessments of classification accuracy were conducted by helicopter reconnaissance in April, 1987. These results will be discussed later in this report.

4. MAP CREATION

Thematic maps were produced using the themes generated through the maximum likelihood classifier. These files were run through an ink jet plotter, which produced colour maps delineating 12 vegetation/cover types.

Maps were produced in both 1:250,000 and 1:125,000 scales.

5. SIGNATURE FILE ACQUISITION

During the initial "final" classification of the Wapawekka map sheet, 28 signature files were used by the system. As a result, an unacceptably high total of 53 hours batch time was required to complete the image.

To reduce the batch time required, signature files generated for various themes were updated by values derived from each training area. This contrasted with the previous method of allowing each signature file derived from each training area to stand as a separate entity for the purpose of classification.

This revised methodology also consisted of selecting nondecimated subareas from within the large image as opposed to appending distinct subareas from the large areas as had occurred originally.

Maxima peaks were also developed from data gathered from the large image.

Test runs using these maxima to classify smaller subareas allowed decisions to be made on the suitability of the signature files to be applied to the larger image.

This method also accounted for greatly reduced batch time for classification of the entire image.

The digital separation of cover types was not improved, however, as the related histogram values are not altered through the enhancement functions.

In order to enhance the digital classification, Bank Ratioing would provide the best option. Different combinations can be utilized until the best separation of a particular cover type is achieved.

6. RESULTS (MAP 1)

6.1 Map Accuracy Assessment Using Forest Inventory Map Data For Comparison

Review of the maps produced indicated that vegetation patterns were consistent with those exhibited by FIM's and aerial photography. May errors in classification, when examining results on a pixel-by-pixel basis, appeared to be caused by errors in superimposing the forest inventory data directly on to the digitally produced map. Slight differences in UTM locations inherent in using the geometric correction task later showed up as a classification error as pixel location was also shifted slightly between maps.

Table 2 contains a comparison between digital classification results and corresponding forest inventory categories, based on the above pixel-by-pixel analysis of both map types.

Classification problems were apparent with the open jack pine classification, which was confused at times with open bog areas. Confusion also existed between open bog and treed bog, as well as treed bog and solid conifer stands.

The latter two problems would be similar to the normal problems associated with visual interpretation of aerial photography, i.e. when does open bog become treed bog, treed bog a conifer stand, etc. Based on this, these types of "misclassification" should not be interpreted as representing a major impediment to achieving a useful finished product.

Analysis of individual pixels resulted in an average agreement of 58% between the FIM system and the acquired digital classification. Accuracy range went from a high of 95% for water bodies, to a low of 2% for the willow/shrub class. Results of individual cover type accuracies are presented in the following section.

6.1.1 Water Bodies (95%)

Edge pixels comprised the bulk of the misclassification in this theme. Confusion also resulted from standing water in open bog cover, and small water bodies not shown on the maps selected for comparison.

Table 2.
A Contingency Table of Sample Units from the Landsat Thematic Maps to the Forest Inventory Maps.

Landsat Theme	Forest Inventory Categories (%)						
	Water	Soft-wood	Hard-wood	Mixed-wood	Treed Bog	Open Muskeg	Brush-land
Lakes	95.0	1.4	0.0	0.7	0.7	0.7	1.4
Coniferous Forest	0.1	64.5	1.6	8.6	20.5	2.5	2.1
Deciduous Forest	0.0	10.8	65.7	16.6	2.9	0.0	3.9
Deciduous Mixed Forest	0.0	23.4	21.0	27.5	20.2	1.2	4.2
Treed Bog	0.4	17.5	2.5	3.2	51.1	23.2	2.1
Open Bog Marsh	0.0	0.0	0.0	0.0	52.5	40.0	7.5
Willow/Shrub	0.0	2.2	6.5	8.7	45.7	34.8	2.2
Open Jack Pine	0.0	29.5*	0.0	0.0	34.1	34.1	2.3

* not distinguished from the general softwood category.
- Table comprised of values determined by SRC staff using digital map superimposed upon FIM at 1:25,000 scales.

6.1.2 Softwood Dominant Mixedwood (64.5%)

A large portion (21%) of the misclassified areas were shown as treed bog on the forest inventory maps. A further 9% was designated as hardwood dominant mixedwood. The remaining 5% of the disagreement occurred in areas of open bog and willow swamps.

Possible causes for confusion would include softwood understory occurring in areas classed as bog on the dated FIM's used, various willow species creating genuine feature space overlap between the two classes, or the original FIM failing to show all islands of timber within bog areas.

6.1.3 Hardwood Dominant Mixedwood (82.7%)

Of the slightly more than 17% confusion shown in this classification, 11% of the misclassified pixels were placed in the softwood dominant mixedwood class. The remaining 6% appeared as open bog or willow swamp cover types.

The 11% confusion with the softwood dominant mixedwood class may actually be the result of a proper classification being performed by the system, but showing up as an error when compared to the FIM. This may be due in part to the "lumping" that sometimes occurs when creating maps from aerial photos. While a classification of hardwood dominant mixed may be valid for a large stand type, specific areas within the larger stand may well have a larger proportion of softwood than the mean, which may lead to classification "errors" when pixel sized areas are subjected to analysis.

The remaining 6% of pixels classed as bog or willow swamp may be due either to genuine overlap in some reflectance values, or slight impurities existing in the training areas selected.

6.1.4 Treed Bog (51%)

Misclassification occurred primarily in the transition zones between open bog and solid conifer stands. A total of 18% of the errors in this classification appeared as coniferous forest on the cover type maps. A further 23% of the errors occurred through treed bog showing up in the open bog classification, with the remaining 8% of the errors present in the deciduous or mixedwood classes.

Again, the main problem here appears to be one of cover densities associated with a conifer stand vs. treed bog, treed bog vs. open bog, etc.

There may also be fairly significant numbers of edge pixels associated with the interface between these classifications, as well as small areas of denser softwood within open bog and sparsely treed bog that may result in errors.

6.1.5 Open Bog/Marsh (40%)

Classification errors were almost exclusively in the treed bog classification. This would also involve the question of a "judgement call" on what constitutes open bog as opposed to treed bog in terms of Crown closure percentages. General agreement existed between the digital classification for marsh habitat and the marsh designation on the FIM's.

6.1.6 Willow/Shrub (2%)

Totally unsatisfactory results were obtained probably due to reflectance overlap with deciduous or deciduous dominant mixedwood classes.

Unless much more detailed work is to be done, this class should be deleted.

6.1.7 Open Jack Pine

There was no detailed comparison performed to assess the percentage accuracy level of this classification.

Based on personal knowledge of portions of the study area, digital classification performed well in delineating open jack pine stands.

Visual interpretation of some areas did, however, indicate that some confusion may exist between this class and open bog in certain areas.

6.1.8 Burns (98%)

Burn classifications were entered using manual themeing, based on visual identification of burn perimeters.

Year classes were included by cross-referencing burn areas to a chronological burn map composite produced by Saskatchewan Parks, Recreation, and Culture, Forestry Branch.

6.2 Map Accuracy Assessment Based on Aerial Reconnaissance

Further assessments of classification accuracy were performed through helicopter reconnaissance in April, 1987.

While this type of ground truthing does not allow a quantitative analysis of accuracy from a qualitative standpoint, vegetation cover patterns were accurately reflected on the map produced through digital analysis.

The comparison of some specific cover types, including the willow/shrub class, open bog/marsh, and treed bog, indicated a higher level of accuracy was obtained through digital analysis than was reported when FIM's were used for checking accuracy on a pixel-by-pixel basis.

As mentioned previously, a considerable portion of "misclassified" pixels were considered to be misclassified on the basis of subjective interpretation as to what constituted open bog vs. treed bog, and treed bog vs. conifer stand.

Aerial observations showed good correlation between digital classification and actual stand compositions, certainly more than the FIM comparison would indicate.

Problems were exposed, however, in the open jack pine class.

Table 3.
Results of Final Classification of the Wapawekka Map Sheet and Resulting Accuracy Levels

Cover Type	CFFDRS Fuel	Type Correct (%)	Error (%)
1. Water bodies	---	95	5
2. Softwood	C-1, C-2, C-3, C-7	86	14
3.Hardwood	D-1	83	23
4. Deciduous Mixedwood	M-2	28	72
5. Treed Bog/ Open Bog	C-2, 0-1	82	18
Mean Accuracy Level (excluding Deciduous Mixedwood) 87%			

While open jack pine stands were accurately delineated, there was a considerable amount of confusion introduced as a result of some open bog/tamarack areas showing up as open jack pine.

More work would be required to purify this class, or else it should be eliminated from future maps.

Table 3 contains the accuracy assessment of the main cover types represented in the final classification of the map sheet.

7. COST/BENEFIT

During the course of this demonstration project, a large portion of computer interactive time was spent on learning the various tasks involved, determining proper classification methods, and altering classification procedures where necessary.

In view of the fact that this is in essence a "one-time" expense, the following cost/benefit analysis has been formulated on the premise that image analysis will be performed by competent, knowledgeable operators, with no "learning" expenses included.

Total operator time associated with the final classification of the Wapawekka map sheet was 9 man-days of interactive time, as well as associated batch processing time required by the system.

The cost comparison between obtaining a forest fuel classification via traditional aerial photography and photogrammetric methods, as opposed to classification using digital analysis is presented in Table 4.

Obviously, there is a vast disparity in the costs involved with the two methods.

In addition to the monetary implications, the use of aerial photography results in substantial time delays between acquisitions of air photos and completion of a map. This results in information being somewhat dated by the time that it becomes available for use.

Conversely, remotely sensed data can be obtained very quickly, and, depending on the complexity of analysis to be performed, a finished product could conceivably be produced within three weeks of the imagery date.

Clearly, if accuracy levels obtained through digital analysis prove acceptable, a vast saving can be realized in a project of this size, with the added benefits of a more current data base to use during the decision making process.

Table 4.
Relative Cost of Map Production Using Photogrammetric Methods vs. Remotely Sensed Data

	Photogrammetric	Remote Sensing
Raw Data Acquisition	$85,000.00	$ 850.00
Processing Costs	96,000.00	2,240.00
Map Production	81,000.00	1,080.00
Colour Check	41,600.00	0.00
Base Mapping	100,000.00	0.00
Total Cost	**$403,600.00**	**$ 4,170.00**

Photogrammetric costs based on figures supplied by Prince Albert Forestry personnel.
Remote Sensing cost based on demonstration project requirements and production of 50 applicon maps.

8. CONCLUSION

Based on the results obtained from this project, digital analysis must be considered a suitable option for classifying forest fuels.

In terms of timely, cost-effective production of suitable products, this technology is vastly superior to the old methods involving photo interpretation and manual production of FIM's.

Updating information is also a much easier task, as the use of multi-date imagery allows changes to be mapped on a regular basis, virtually "as required."

Some of the classification problems discussed earlier may also be alleviated via multi-date analysis and this possibility should be explored at a later date.

Thematic maps produced through digital analysis could potentially become an integral part of both presuppression planning, and formulation of actual suppression strategies.

These maps could also see use in conjunction with the Canadian Forest Fire Danger Rating System, and Fire Behaviour Preduction System, as developed by the Canadian Forestry Service.

It must be recognized, however, that new technology of virtually any description will meet with a certain amount of resistance and skepticism.

The successful integration of these maps into the normal operational procedures of fire managers will require a concerted effort.

If this type of information is to be used in the future, it will depend largely upon the successful orientation of these managers to the benefits and **practical** applications available to them through its use.

The validity of the technology and the accuracy of the resulting maps should also be demonstrated at the field level so that a credibility can be established and built upon.

Failure to place sufficient effort into these initial phases will almost certainly result in the overall rejection of remotely sensed data as a valid tool in fire management planning for the future.

9. REFERENCES

Head, W.K., D.W. Anderson and J.G. Ellis. 1981. The Soils of the Wapawekka Map Area 73-I Saskatchewan. Extension Publication 303, Saskatchewan Institute of Pedology Publication SF5, University of Saskatchewan, Saskatoon. 108 pp.